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EXCELENCIA SEVERO OCHOA

Constraining soil dust emissions from natural and anthropogenic sources

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Thanks to Sara Basart, Oriol Jorba, Laura Cifuentes, María Gonçalves-Ageitos and others

25/06/2018

ICAR X – Bordeaux, France

Dust sources – natural and anthropogenic

- **Anthropogenic** – dust source associated with agricultural land use
  - Mineral dust only (no urban pollution)
  - Not considered: Emissions from vehicles (dirt roads, tillage, recreational use); military operations
  - Not considered: Indirect anthropogenic sources, e.g. hydrological
- Dust emissions from anthropogenic sources can **impact daily life**, not only in (semi-)arid areas
  - 1930s Dust Bowl, USA
  - Traffic accidents, e.g. 2011 in northern Germany
- **Global impact?**

Wikipedia (Photo: Arthur Rothstein)

spiegel.de

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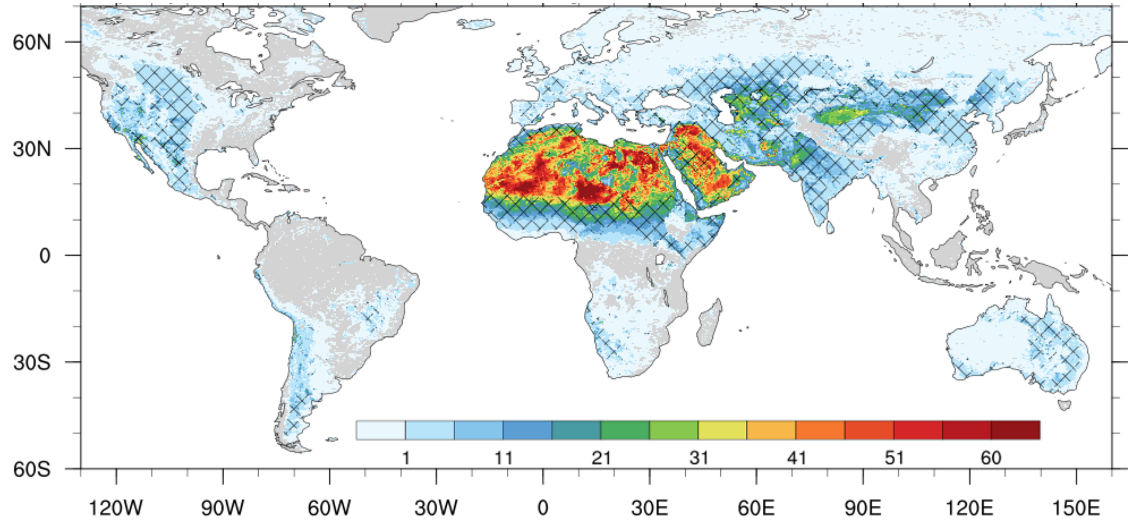
Dust from anthropogenic sources

- Estimates range from <10 to 50%
  (e.g. *Tegen and Fung*, 1995; *Sokolik and Toon*, 1996; *Tegen et al.*, 2004; *Mahowald et al.*, 2004)
- *Ginoux et al.* (2012) estimated that anthropogenic sources contribute 25% to total dust emissions
  - Areas with > 30% land use (*Klein Goldewijk*, 2001) were considered as anthropogenic sources
  - FoO of MODIS DeepBlue dust optical depth (DOD) exceeding a threshold of 0.2 (resolution 0.1° × 0.1°)
  - Offline dust emissions: *Ginoux et al.* (2001) parameterization with uniform threshold wind speeds, combined with FoO

FoO of DOD > 0.2

From *Ginoux et al.* (2012)



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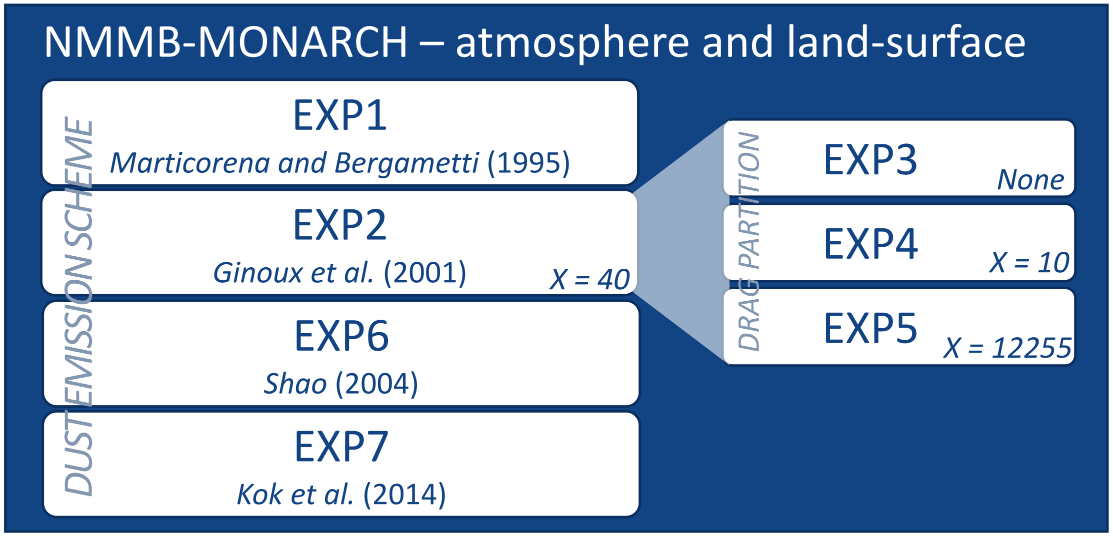
Advanced constraining using numerical experiments

- Combine recent advances from *Ginoux et al.* (2012) with integrated numerical modeling system
  - **Fully coupled dust emission** parameterizations
  - Dynamic **threshold friction velocity** for sediment entrainment
  - Satellite-based representation of **aerodynamic roughness length**
  - **4D dust concentration field** allowing in-depth evaluation
- NMMB-MONARCH (*Perez et al.*, 2011; *Badia et al.*, 2017)
  - Multiscale Online Non-hydrostatic AtmospheRe CHemistry model
  - Global setup (1° x 1.4° horizontal resolution, 24 layers)
  - Currently 1 year
  - FoO used for tagging and as a constraint (no scaling)



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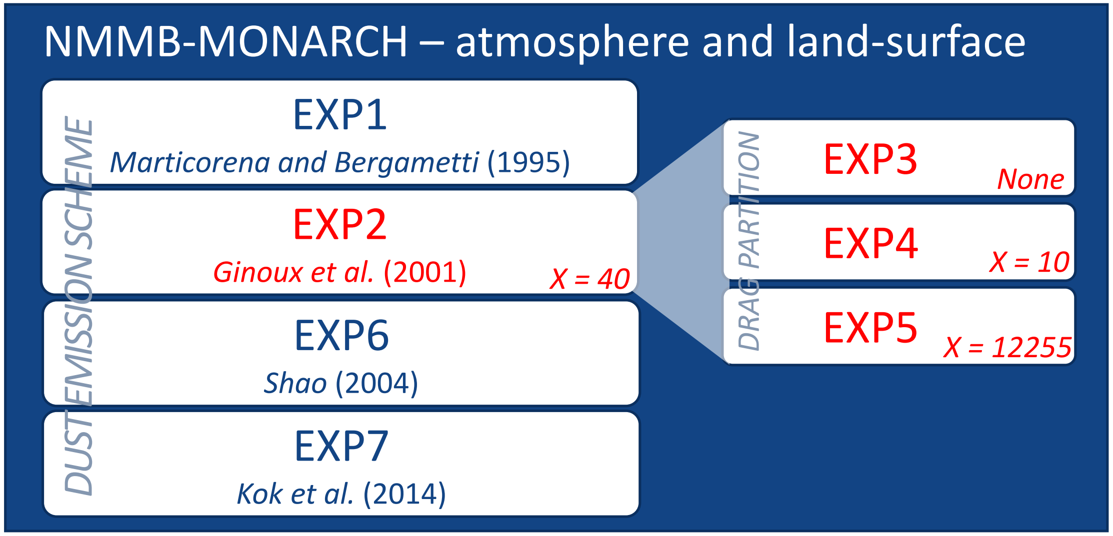

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Drag partition experiments

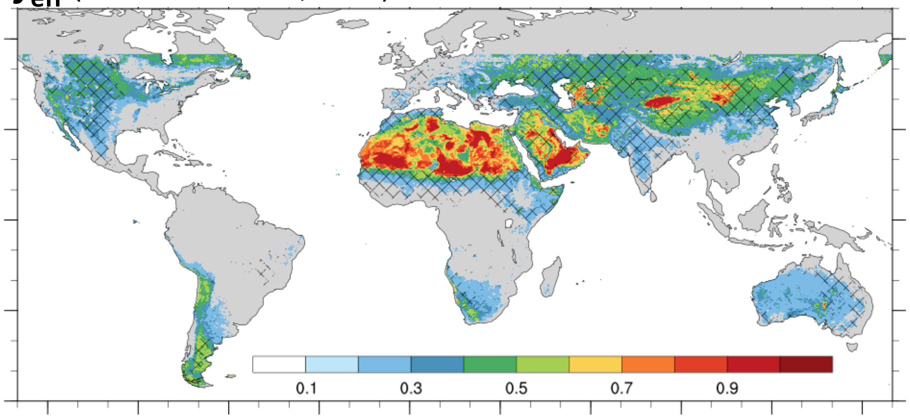
- **Drag partition:** Drag on roughness elements and on ground surface
- EXPs 2-5:
  - **Dynamic threshold velocity** for sediment entrainment (*Iversen and White*, 1982)
  - **Drag partition** from *Marticorena and Bergametti* (1995):

$$u_t = \frac{u_{t0}}{f_{\mathrm{eff}}} \qquad f_{\mathrm{eff}} = 1 - \frac{\log \frac{z_0}{z_{0s}}}{\log\left(0.7\left(\frac{X}{z_{0s}}\right)^{0.8}\right)}$$

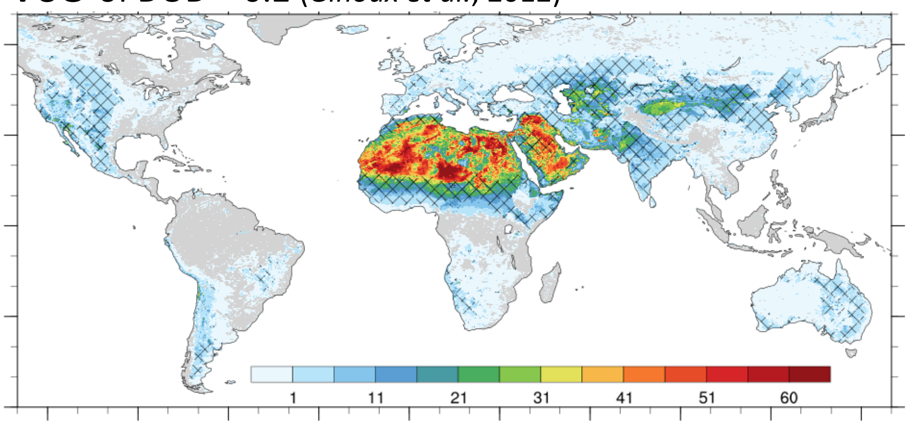
- Estimates of *X* range from 10 to 12,255 cm (*Marticorena et al.*, 1995; *Pierre et al.*, 2014; *MacKinnon et al.*, 2004)
- Other drag partition schemes to be tested in the future

Aerodynamic roughness length (z_0)

$\boldsymbol{f}_{\mathbf{eff}}$ (*MacKinnon et al.*, 2004)



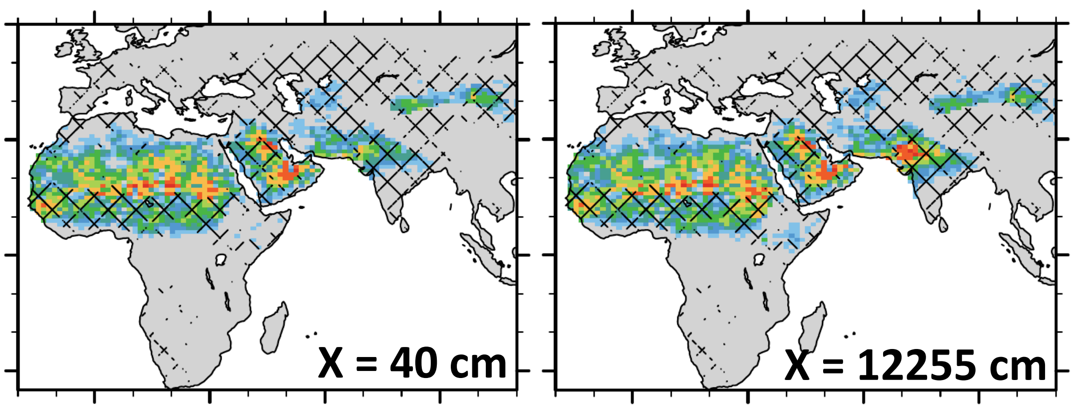
FoO of DOD > 0.2 (*Ginoux et al.*, 2012)

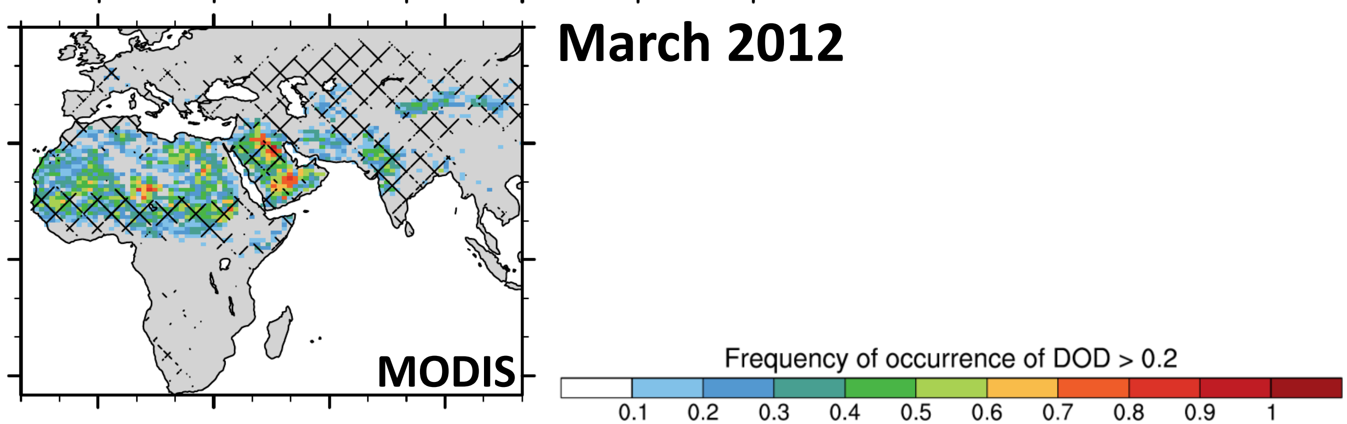


- Combining static (non-vegetated) roughness length (*Prigent et al.*, 2012) with dynamic roughness length from LAI
- FoO provides information about the frequency of sediment emission (→ <u>entrainment threshold</u>, u_{*t})
- Drag partition coefficient f_{eff} closely resembles MODIS FoO
- z_0 or drag partition is a **key element** to reproduce observed FoO

Effect of drag partition on FoO

- Spatio-temporal co-location between MODIS and model data
- Drag partition strongly affects FoO
- Changes in FoO most pronounced in SW Asia and E Central Africa
- Comparison with MODIS helps to evaluate source activity





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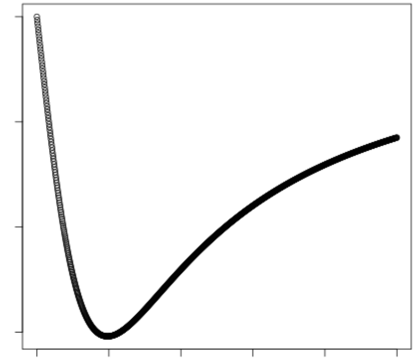
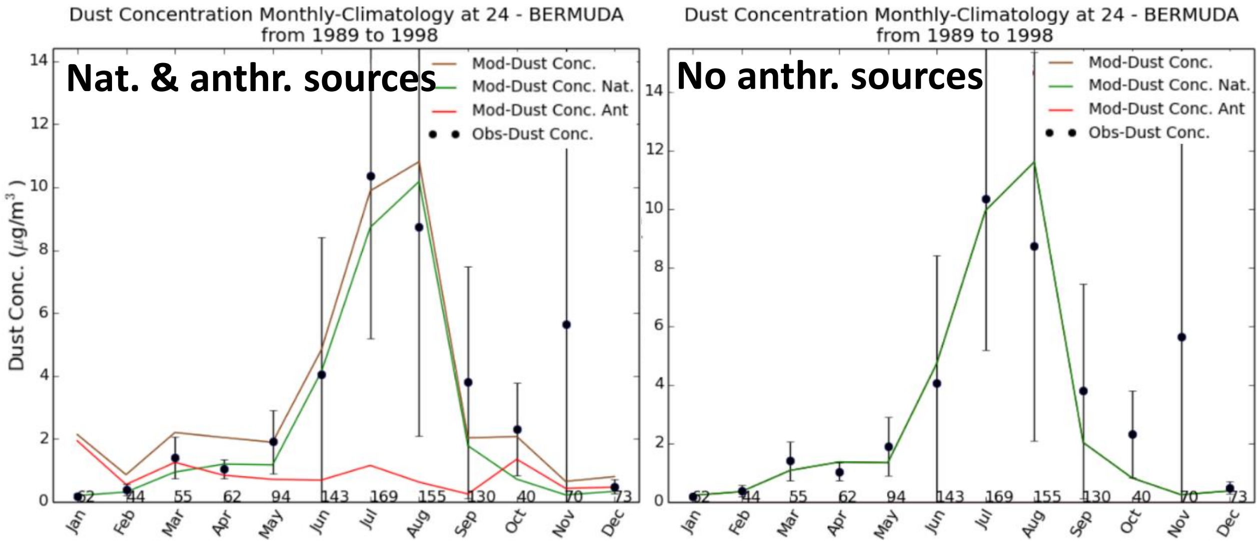
Constraining the dust cycle with observations

- Obtain a best-estimate by minimizing the error between model results and suit of measurements (*Cakmur et al.*, 2006) → model optimization factor
  - ➢ DOD [AERONET, MODIS], dust concentration, dust deposition



- Evaluating spatial and temporal distribution of dust, relative amount of dust load and deposition, etc. to **identify model weaknesses** and **test hypotheses**



Obs. data: University of Miami Ocean Aerosol Network, D. L. Savoie and J. M. Prospero

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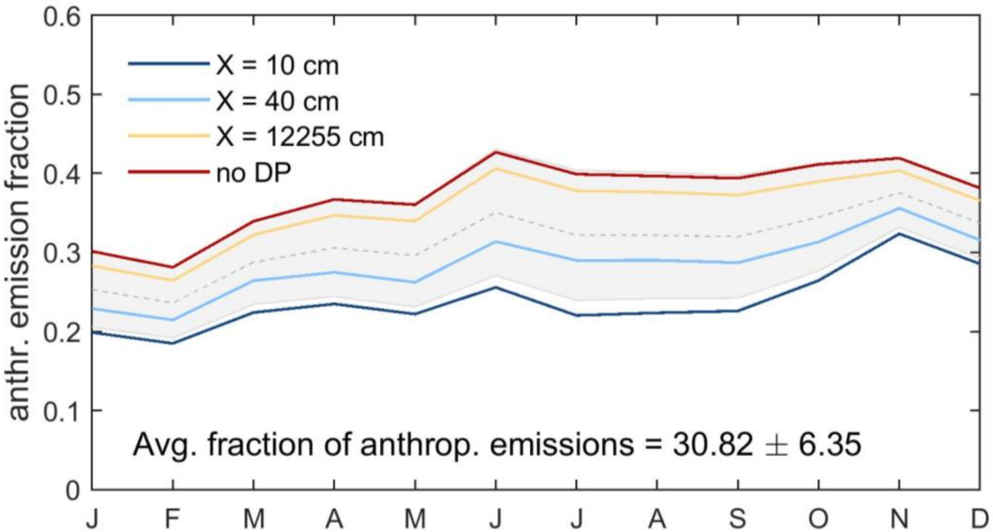
Anthropogenic contribution – preliminary results



Region	Anthro. emission fraction (avg ± std)	Regional contribution to total emission (avg ± std)
N Africa	12.3 ± 5.4	55.1 ± 13.6
S Africa	1.4 ± 2.0	0.2± 0.1
Middle East	32.2 ± 9.0	28.6 ± 9.4
NW Asia	60.3 ± 19.9	6.9 ± 4.4
SW Asia	45.0 ± 12.1	2.3 ± 1.7
NE Asia	44.7 ± 12.0	8.7 ± 3.7
Australia	100.0 ± 0.0	0.0 ± 0.0
S America	30.3 ± 15.3	0.7 ± 0.4
N America	82.5 ± 8.6	0.7 ± 0.7
Europe	72.7 ± 6.9	1.0 ± 0.6

- Weighing of individual experiments based on total error after optimization and case probability will improve robustness of estimate
- Problems in SH due to static roughness length and source attribution (to be updated)

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Near-future outlook

Main uncertainties are currently:

- **Land-surface conditions, in particular for coarse global grid**
  - Higher-resolution global model runs
  - Refined use of source attribution using new dataset and scenarios
  - <u>Expansion of observational constraints</u>
- **Dust emission**
  - Use of additional dust emission parameterizations:

<u>Saltation-based</u>:	*Marticorena and Bergametti* (1995)
	Shao (2004)
	Kok et al. (2014)
<u>Aerodynamic entrainment</u>:	*Klose et al.* (2014)
➢ <u>Threshold friction velocity</u>:	*Shao and Lu* (2000)
➢ <u>Drag partition</u>:	*Raupach et al.* (1993), *Shao and Yang* (2008)

- **Meteorological dust drivers**
  - Parameterization for moist convective dust storms (<u>haboobs</u>) (*Pantillon et al.*, 2016)

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Thank you

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